International Hurricane Research Center/Florida International University
Areas of Research for the Period July 1, 2005 through June 30, 2008

Principal Investigator: Stephen Leatherman
Program Manager: Carolyn Robertson

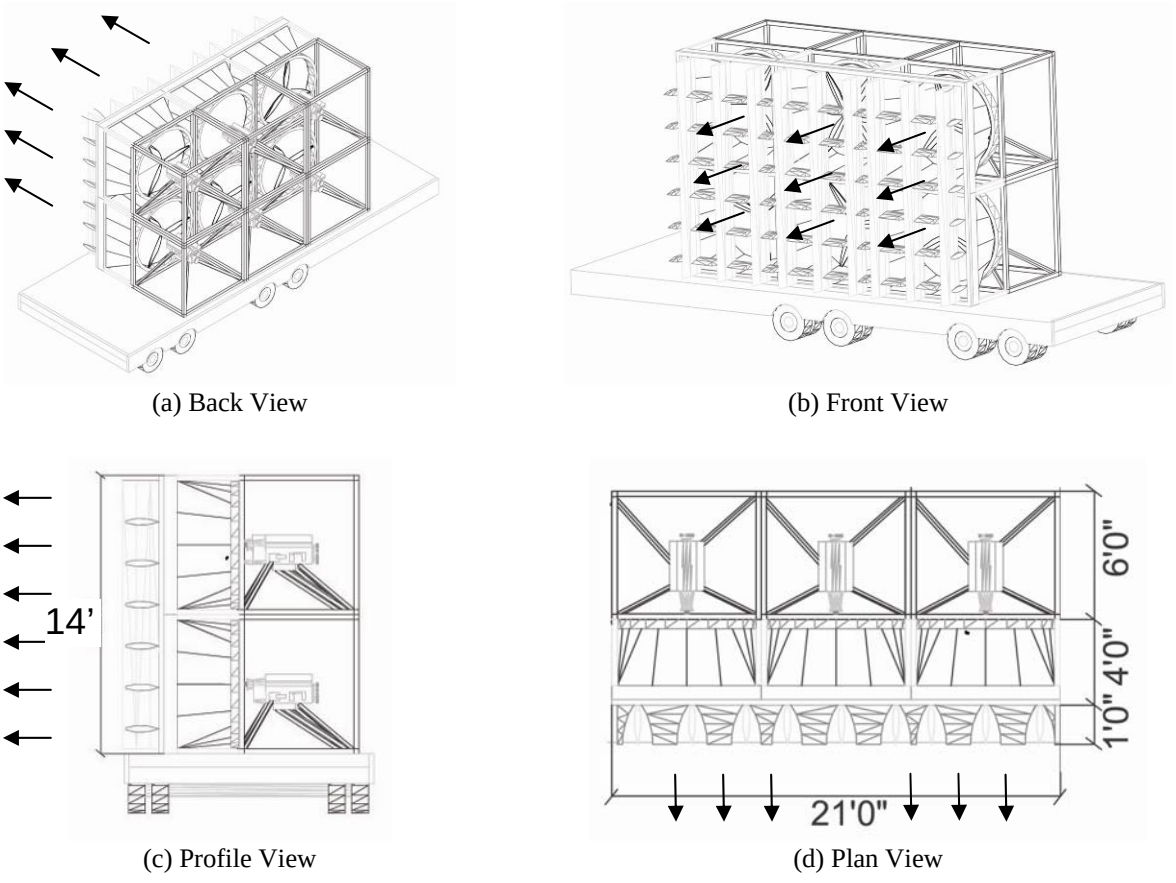
Annual Report to the Florida Legislature

The IHRC will consult with DCA and assist in writing the annual report and accounting of activities under section 215.559, Florida Statutes, Hurricane Loss Mitigation Program. The report will be submitted by DCA to the Speaker of the House of Representatives, President of the Senate, and the Majority and Minority Leaders of the House of Representatives and Senate by January 1, 2006, 2007 and 2008.

Hurricane Loss Reduction Devices and Techniques

Full Scale Simulation of Wind, Water and Structural Interaction

FIU is building a new testing apparatus, the Wall of Wind, which will be completed mid-summer 2005. The experimental setup is illustrated in Figure 1. The fan array will consist of six modular steel rectangular frame units that house fully assembled Chevrolet ZZ502 Big Block Crate Engines that produce 502 hp at 5200 rpm and 567 ft/lbs of torque at 4200 rpm. Each engine spins a belt-driven planetary drive unit, which turns two 80+ inch counter rotating propellers inside of a 2.1 m (7 ft) round aluminum duct situated inside the frame. This duct transitions over 1.2 m (4 ft) into a 2.1 m X 2.1 m (7 ft X 7 ft) square cross-section so that the units can be stacked without producing gaps at the exit. To suppress the engine, drive unit and propeller noise, a cowling lined with anechoic material (not pictured) will encompass the entire array. A four-axle trailer—stiffened to carry the dead weight of the components and to resist dynamic wind loading—will support the entire assembly. Collapsible outriggers (not shown) attached to the frame will provide additional resistance to overturning moment and lateral stability. At the cross-section of the exit, (1) an articulating mesh of interlocking neutral-shape airfoils (rudders) will direct the air flow horizontally and vertically and (2) a water injection system will simulate wind-driven rain. Following the recommendations of Blocken and Carmeliet (2004), wall-mounted and free-standing wind driven rain gauges will be employed to measure vertical and horizontal rainfall intensities.



(a) Back View (b) Front View

(c) Profile View (d) Plan View

Figure 1. Wall of Wind experimental configuration (cowling and outriggers removed)

The resultant wind/rain field will travel 3-5 m (10-16 ft) from the exit of the Wall of Wind to the test subject—such as a corner or a part of a wall of a full size single story house—where high-speed cameras will monitor its degradation. If appropriate to the experiment, test subjects will be instrumented with pressure taps, load cells, moisture meters, strain gauges and/or displacement transducers.

At the discretion of the program coordinator, FIU will conduct research in the following areas:

1. It remains unclear what level of wind event (eg, Saffir-Simpson Category 1,2,3...) test procedures—developed by ASTM, UL and others—actually represent. The Wall of Wind will (1) establish these performance bases, (2) adapt the ongoing complex, research-grade experiments to simplified tests for the product certification industry, (3) propose these "minimum requirement" methods to recognized codes and standards organizations, and (4) develop separate wind and rain resistance "ratings" criteria for building products similar to the NHTSA Five Star Crash Test and Rollover Ratings that assess vehicle crash worthiness.
2. The Saffir-Simpson Hurricane and Fujita Tornado Intensity Scales are largely based on expert opinion, not direct comparison of damage to measured wind speeds. The Wall of Wind establish this foundation to (1) assess hurricane landfall intensity as a function of damage to the building stock, (2) evaluate building codes post-disaster and (3) forensically reconstruct the wind field from damage when wind speeds are not available.

3. Alicia demonstrated the devastating effects of gravel ballast on skyscrapers. Andrew exposed the danger of inadequate roof to wall connections. In both cases, the building codes changed in the following years to prevent reoccurrence of these events. Today's concern—as a result of Charley—is water intrusion. While many homes survived structurally, they experienced enough rain penetration to require massive interior restoration and occupant displacement until the completion of repairs. The Wall of Wind, which can simulate wind-driven rain, is the perfect tool to develop the upcoming policy changes to reduce water damage from future hurricanes.
4. Wind must travel over and around buildings, which causes flow separation at the structures' edges in high winds. In these zones, suction pulls on the structure. Lowering that suction 10-20% at the edge or 50% at the corners could significantly lower roof damage. Research in the Wall of Wind will lead to modified aerodynamic edge shapes to suppress vortex generation and ultimately reduce critical edge uplift pressures.
5. In addition the IHRC will continue investigating the production and behavior of windborne debris generated by tropical cyclone winds. Ultimately, this research seeks to improve risk consistency in existing building codes and standards (e.g., ASTM E1886/E1996, FBC §1626 and SBCCI SSTD 12) and to develop new testing protocols. In particular, the IHRC will avail itself to the wall-of-wind apparatus and vacuum chamber.

Tropical Cyclone Conditions in Typical Florida Neighborhoods

The pressure loading on low-rise buildings that reside within the lowest 5% of the atmospheric boundary layer is deeply sensitive to the turbulence characteristics of the wind field, which in turn, is dependent on the roughness of the upwind terrain. Accordingly, neighborhood layout and landscaping affect this phenomenon significantly and play a role in modifying the impact of hurricanes on a site- or neighborhood-specific basis.

The primary goal of this research is analysis of field data of wind pressures and wind tunnel studies on models of houses located in a typical Florida neighborhood. Field data collected during various hurricane seasons has provided near-ground level hurricane-strength wind speeds and pressure coefficients for six houses having the complex roof shapes and architectural features, typical of residential neighborhoods. This unique data will be used to establish what the real wind conditions were and whether the storm produced winds and wind load effects that were below, at or above code levels.

The issues highlighted above serve as the primary motivation to study pressure variation on roofs in this proposal. These investigations will initiate by analyzing information from surface wind data available from the wind anemometers on the houses to determine the turbulence characteristics compared with wind towers data. As a complement to the analysis of field data and to improve our understanding of the phenomena, wind tunnel studies will be performed to create a database of pressure coefficients and forces as a baseline for future studies on the load variation observed in the field.

Quantifying Effects of Pruning on Tree Response from Wind Loading

This project seeks to determine the influence of pruning on wind-induced shade tree canopy dynamics. Two objectives will be achieved:

- Determine if pruning trees according to ANSI A-300 standard can reduce the force of wind against a shade tree canopy compared to non-pruned trees
- Determine the impact of pruning dose (amount of removed foliage) of stresses on the trunk.

When trees fail by losing limbs or by lodging, significant economic loss, serious injury, and death can occur. Downed trees can impede evacuation routes as they fall on major roadways in storms. Trees' inherent mechanical properties are designed to resist failure or limit it to smaller less significant parts in order to protect the trunk and scaffold branches. A few studies found safety factors in the design of trees (e.g. Mattheck et. al., 1993; McMahon, 1973; Niklas, 1994, 1999; Tateno, 1991).

Pruning is the most common cultural practice used by arborists and urban foresters to care for established trees in urban environments. It is often recommended as a means of reducing risk by minimizing the potential of trunk or branch failure. Pruning seeks to reduce risk by reducing stresses on the branches and trunk but there is little data to support the practice. This study will evaluate the acute effect of pruning on the stress experienced by live oak stems under generated wind loads. At the end of this study researchers will have some understanding of whether pruning can influence forces in a tree canopy, and if so by what degree. It will also provide an understanding of the impact of pruning dose on stresses within the canopy. The results will help refine A-300 pruning standards and professional practices and provide a starting point for further research in pruning technology. In addition the findings will help guide communities to develop meaningful pruning treatments for shade trees.

Wind vs. Surge Damage to Coastal Residential Housing

Houses near the coast can be impacted by hurricane-force winds or storm surges or both. Differentiation of these impacts on residential housing has not been directly determined, yet it has important implications as wind damage is privately insured and flood damage is insurable by FEMA. Hurricane Ivan and to a lesser extent Dennis graphically demonstrated the impact of storm surges in the panhandle area during the past two years. Hurricane Charley also had the potential to generate a large surge as a Category 4 hurricane. However, there are no direct measurements of storm surges during hurricane landfall, and there is confusion regarding whether wind or water has resulted in the damage of many structures. Therefore, we plan to initiate a program of setting up flow depth indicators and videocams prior to hurricane landfalls to obtain this critical information for damage determinations. This project will require a four-wheel drive truck and trailer for deployments.

Age Based Wind Retrofit Selection for Existing Public Facilities

Numerous Florida public structures were built in the 1960s – 1980s. Many of these structures are also designated as public shelters. The wind design provisions for buildings have changed, becoming more stringent since the earlier building boom years. Older building structures may have certain amount of vulnerability because of the changes in the wind design provisions. It is obvious that the degree of current wind vulnerability of various public facilities in the state may vary, based on the structure age, geographic location and construction practices. After the recent series of hurricanes, it has become obvious that aging facilities will require strengthening to become safe from wind damage. However, there is no current guideline available to the owners, engineers and building compliance officials to judiciously choose various wind retrofit options to reduce the vulnerability of the structure. The proposed study is geared towards filling the gap in knowledge

base for a systemic choice of wind retrofit options currently available. The objectives of the proposed study are as follows:

- To develop a chronological list of various building phases in the state, and example of typical public facilities built during each phase.
- To select various possible wind retrofit choices for public facilities available in the market
- To develop a guideline for the selection of such retrofit choices based on building age, type and cost effective vulnerability reduction.

A guideline to determine the wind vulnerability of existing public facilities and cost/benefit effectiveness for various retrofitting measures will be available for wind mitigation usage. The proposed study will benefit the wind mitigation needs of both state/local organizations and general population in the state. A vast number of existing public buildings in the state do not have sufficient wind resistance, as per current standards. Their levels of wind vulnerability are unknown. Owners willing to retrofit their facilities, and with limited available funds for such purposes, will have available a rational guideline to take appropriate measures for cost effective strengthening.

State-Wide and Focused Surveys to Assess Effectiveness of RCMP Program

Surveys previously conducted by the IHRC, have helped establish a baseline from which we can assess the effectiveness of the RCMP program in contributing to hurricane loss reduction in Florida. This information is valuable to state agencies and policy-makers in understanding the benefits derived from the RCMP, and it will also help in modifying and fine-tuning of the program to maximize the benefits for the resident of Florida. Research during the 2005/2008 period will include new statewide and target surveys to assess the effectiveness of the RCMP program to be selected by DCA.

Programs of Education and Outreach to Convey the Benefits of Various Hurricane Loss Mitigation Devices and Techniques

Activities will build on the foundation of work initiated during previous grant periods including outreach initiatives, such as the Deerfield Beach-based Hurricane Warning Project, the Governor's Hurricane Conference, the National Hurricane Conference, the South Florida Hurricane Conference, the Southeast Builders Conference and the Miami-Dade County Local Mitigation Strategy. In addition the IHRC will visit local elementary and high schools and other venues with our traveling laboratory fully equipped with demonstrative wind tunnel, hurricane simulator and model wall of wind. This will allow the work conducted under this grant to be showcased and shared with others as a way of promoting hurricane-loss mitigation and the objectives of the RCMP. Research components will also be complemented with visualization techniques such as computer animation in order to provide a visual representation of the research findings.